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Geometric-Optical Modeling of Directional Thermal Radiance for Improvement of Land Surface Temperature Retrievals From MODIS, ASTER, and Landsat-7 Instruments

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1. Introduction

The general objectives of this project were to improve understanding of the directional emittance properties of land surfaces in the thermal infrared (TIR) region of the electro-magnetic spectrum. To accomplish these objectives our research emphasized a combination of theoretical model development and empirical studies designed to improve land surface temperature (LST) retrievals from space-borne remote sensing instruments. Following the proposal, the main tasks for this project were to:

1. Participate in field campaigns
2. Acquire and process field, aircraft, and ancillary data
3. Develop and refine models of LST emission
4. Develop algorithms for LST retrieval
5. Explore LST retrieval methods for use in energy balance models.

In general all of these objectives were addressed, and for the most part achieved. The main results from this project are described in the publications arising from this effort (see list of publications, attached). Below we summarize our efforts related to each of the objectives listed above. For more complete details, the reader should refer to the papers listed at the end of this report.

1. Participation in field campaigns

Throughout the project period, the PI participated in several field campaigns. These included activities conducted in collaboration with Dr. Wan at UCSB, who is the LST scientist on the MODIS instrument team. The PI also participated in field activities conducted in Yucheng, China, in cooperation with colleagues from Beijing Normal University, the Chinese Academy of Science, and Peking University at Namco Lake (4718 m above the sea level, 1920 km^2 in size) on the Tibet Plateau. In addition, research associates funded through this effort participated in field activities conducted in collaboration with French researchers at the French National Institute of Agricultural Research (INRA) at their 5x5 km^2 test site in the Rhone Valley in Avignon France. In each case, directional thermal emission from land surfaces was measured using TIR thermometers mounted on surface-based platforms and aircraft. In addition, the FTIR spectrum of thermal emission from wheat and soil, component temperatures and structural parameters such as leaf area index (LAI) and the canopy leaf angle distribution (LAD) were collected. Synchronous thermal and TIR measurements of wheat and soil background (homogeneous within about 3x3 km^2) were also collected at AVHRR and Terra overpass times.

2. Acquire and process field, aircraft, ancillary data

Activities related to processing and analysis of field, aircraft and ancillary data examined both field-based measurements, and measurements acquired in highly controlled conditions in the Yucheng facility. For each of the field data campaigns, visiting post-docs were supported on this grant to process and analyze the data sets that were acquired. This work was conducted at Boston University, at INRA, and in China, as appropriate. In each case, the data were analyzed for two main purposes. First, analyses were performed to assess the degree of directional dependence in the data, and to relate these properties to the biophysical attributes of the site in question. Second, theoretical models of LST emission were tested using each of the data sets. Based on the results from these efforts, our models were refined to improve their representation of LST emission.

3. Develop and Refine Models of LST Emission

The key objective of this component of the project was to develop improved understanding, and by extension models, of the directional dependence in LST measurements. To achieve this goal, we developed a conceptual model of directional LST emission as a function of surface biophysical properties. This effort was largely completed in the first year of funding, and subsequent efforts were directed towards model testing and refinement using field data. To this end, validation of our conceptual model was also performed in a laboratory using measurements and Monte Carlo simulation. These validation efforts used field data that encompassed a variety surface conditions including agricultural fields, discontinuous crown canopies (conifers), sparse canopy conditions, and using artificial plastic cones and cotton ellipsoids over an isothermal black metal board for which the temperature could be controlled.

4. Development of algorithms for LST retrieval

Through this effort we developed a general approach of knowledge-based inversion of LST. Because the LST retrieval problem is similar (in the sense that LST measurements exhibit strong directional dependence) to the BRDF problem in the reflective wavelengths, this effort was conducted together with the Terra MODIS BRDF/albedo project team. This problem is somewhat ill posed, and a priori knowledge, either general or specific, must be accumulated and appropriately included in the inversion so that the limited information acquired from the remote sensing signals can be effectively used to retrieve the most uncertain variables of interest. To this end, we developed methods that exploit information related to the land cover properties of land surfaces to help constrain the inversion solution. One unresolved problem is that our knowledge in TIR bands about the land surface is much poorer than in the visible and NIR bands. We have made some progress on this topic, but this question requires further investigation that is beyond the scope of this project.

5. Test the use of LST retrievals for use in energy balance models.

The final component of this project involved efforts that explored the utility of LST measurements for land surface energy balance modeling. These efforts focused on relationships between the remotely sensed LST and the surface aerodynamic temperature. To this end, the use of LST in two-layer energy balance models was examined, with specific emphasis on the interaction between surface structural properties (LAI) and how they control relationship between LST and the surface aerodynamic temperature.

Publication list:

Friedl, M.A. 2002: Forward and inverse modeling of surface energy balance using land surface temperature measurements, *Remote Sensing of Environment,* Vol. 79, pp. 344-354.

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